Radiation Dose Evaluation for Radiotherapy Workers at Unand Hospital Using Four-Element Thermoluminescence Dosimetry

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ABSTRACT

Radiotherapy is a non-surgery therapy that employs ionizing radiation like X-ray or even radiation to cure cancer as a curative activity. Radiation dose rate analysis is required for the person who worked on radiotherapy to strengthen safety precautions for radiation protection, notably in oncology radiation. The research attempted to disclose time trends and radiation dose rate exposure variations among personnel in radiotherapy installation. Radiation dose examination utilizing four-elements TLD received from 16 respondents grouped into six groups (radiation oncologist, medical physicist, radiotherapist, electromedicine, nurse, and sculptor). The number of occupancy exposures rose 55.5% from 2018 to 2022. The most significant annual radiation dose rate for 900 patient workloads attained by medical physicists was 0.996 mSv. In addition, electronics receive the lowest annual radiation dose at Unand Hospital. Annual effective dose exposure by radiation is still safe, below national or international regulations. However, a protective improvement process is vital to limit radiation interaction, particularly for medical physicists, who are the most vulnerable to radiation exposure.

INTRODUCTION

Cancer incidents increase yearly and are considered the main factor of death (Wong et al., 2022; Mazonakis et al., 2017). Radiotherapy is a non-surgical treatment that uses ionizing radiation, such as X-rays or radioactive sources, to treat cancer (Khan et al., 2022). Besides being applied as non-surgical therapy, radiation therapy could also be applied as curative and palliative treatment. Curative focus on healing cancer. On the other side, palliative improves health quality by reducing cancer symptoms like heavy bleeding, intense pain, and other cancer symptoms.

Radiotherapy has been classified into a couple of groups: teletherapy and brachytherapy (Rosenblatt et al., 2013). Teletherapy is a radiation exposure technique that gives a certain distance from the source of energy to the target. Teletherapy could utilize X-ray as the radiation source or even by using radioactive compounds (Pereira et al., 2014). Nowadays, teletherapy uses radioactive compounds and is getting left behind by medical treatment. The difficulty of waste treatment is one of the reasons radioactive teletherapy is no longer used. Teletherapy is common for Linear

accelerators (Linac) with X-ray as the primary source (Fauziah & Abdullah, 2018; Bilalodin et al., 2020; Bernier et al., 2004). The other therapy radiation is the brachytherapy exposure technique. Brachytherapy is a technique that uses covered-radioactive compounds that are close to the cancer target location (Ghorbani et al., 2017). Brachytherapy aims to give an extra dose (booster) post-main radiation dose using the teletherapy technique.

Ionized radiation used for therapy, such as X-rays or radioactive substances, has advantages from a medical standpoint as well as disadvantages for those exposed to it at work, patients, or even people in general (Calabrese et al., 2019; Cuaron et al., 2011; Donya et al., 2014; Fardela et al., 2021). If radiation is misapplied, it can cause death by causing the disintegration of body cells (Smith et al., 2017). Facility operators must strictly control radiation utilization to control the terrible effects of radiation (Martin et al., 2018). Occupational exposure (including the field medical sector) has to follow international safety standard operational procedures (Miller et al., 2010). International Commission on Radiological Protection (ICRP) determines the average radiation dose limit of 20 mSv/year for five years and never be over 50 mSv each year (ICRP, 2007)

Previously, Alashban (2021) described the effective occupational dose in several medical departments in Saudi Arabia by thermoluminescence dosimetry (TLD 100). As a result, nuclear medicine and cardiac catheterization are exposed to the highest annual effective doses (Alashban, 2021). Report Turkey Occupational Exposure dose in one of the biggest hospitals. Therefore, nuke medical technology on PET/CT accepts more effective dose and skin dose rates than other professions (Elshami et al., 2022). Recently, Meye et al., 2023 exposed doses received by Occupational Exposure in several radiotherapy installations and Nuke Medical in Gabon by using an Optically Stimulated Luminescence (OSL) Dosimeter.

Consequently, Meye 2023 suggested that national IMS and supervisors reduce body dose annually below six mSv to optimize employers' protection (Ondo et al., 2023). According to IAEA (2014), related to radiation protection and radiation safety, Hp (10) represents the whole body, Hp (0.07) for dose extremity, and Hp (3) for eyes dose (IAEA, 2014).

Unand Hospital belongs to Universitas Andalas, which is under Universitas Andalas Management. The hospital was built for 200 beds and supported a complete medical facility based on national regulations. One of the modern facilities in Unand Hospital is a radiotherapy installation. Ionizing radiation can be detrimental to human health, especially if exposed for long periods or in high doses. Hence, it is crucial to monitor the radiation exposure of radiotherapy employees.

The safety of employees at radiotherapy facilities is supported by radiation dose monitoring. Management and medical teams can minimize the risk of overexposure and ensure a safe workplace by keeping an eye on the radiation dose that employees are receiving. The risk of long-term health effects from excessive radiation exposure is decreased with the use of radiation dose monitoring, which helps ensure that personnel do not exceed the limitations. Radiation dose monitoring enables proper regulation and adherence to the treatment plan for both the radiation dosage administered to patients and that employed during medical operations. This is crucial to maximize therapy effectiveness while limiting harm to healthy cells. Workers are exposed to radiation on a regular basis for extended periods in radiotherapy workplaces.

The research focuses on measuring the dose purchased by occupational exposure in the radiotherapy facility of Unand Hospital by using the four-element thermoluminescence dosimetry (TLD 4 elements). This study aims to determine the annual dose rate based on occupational

exposure from 2018 to 2022 as a guideline for the Radiotherapy installation early warning system. In addition, this study also aims to determine the time and dose differences between workers in radiotherapy facilities.

METHODS

The research was a retrospective analysis of the doses received for occupational exposure in a radiotherapy facility from LINAC dual Energy, CT-Simulator, and Brachytherapy Radioactive compound Ir-192. Figure 1 shows the research phases for the equivalent dose received by the entire body at a depth of 10 mm from the body surface (Hp 10) for each occupational exposure in the radiotherapy facility at Unand Hospital from 2018 to 2022.
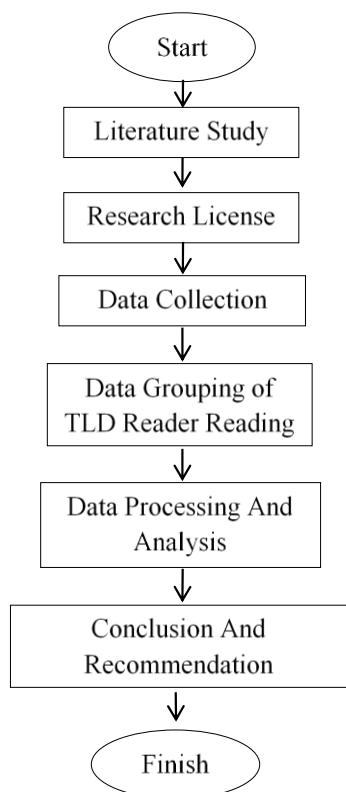
Figure 1 Stages of Research

The annual workload rate is 900 patients. The dose radiation record for 16 occupational Exposures in radiotherapy installation was collected from TLD. The employees classified in this group are radiation oncologists, medical physicists, radiotherapists, electrochemists, nurses, and sculptors.

Four-element TLD was used to measure radiation dose accepted by occupational exposure in the radiation facility. The TLD 4 Elements has specification like Position 1: Filter ABS + Cu (333 mg/ cm^2); Chip TLD 700, thickness 0. 015" Position 2: Filter ABS + PTFE (1000 mg/ cm^2); Chip TLD 700, thickness 0.015" Position 3: Filter Mylar (17 mg/ cm^2); Chip TLD 700, thickness 0.015" Position 4: Filter ABS (300 mg/ cm^2); Chip TLD 600, thickness 0.015" noise dosimeter. Radiation dose adsorbs by TLD 4 Elements interpreted by TLD reader on the accredited department. The reading duration is three months. Therefore, radiation doses accepted by respondents are accumulated for three months. All respondents use TLD 4 elements to measure Hp (10) every three months. Hp (10) dose is directly used without any factor or formula conversion to predict the annual effective amount.

The data were analyzed statistically with the origin software. The data is classified based on the category of Occupational Exposure. Measurable Radiation dose is announced as rate and SD. The research was conducted to improve quality; as a result, ethical clearance is unnecessary. A pair of free electrons and holes will be formed when ionizing radiation hits the TLD material.

The TLD reading value by the TLD reader needs to pay attention to several factors, including the calibration factor, the energy correction factor and the background radiation. The net TLD reading value is calculated using equation (1).

$$Rn = Rt - Rb \qquad (1)$$

Rn is the reading of the net thermoluminescence (TL) intensity in units of nC, *Rt* is the reading of the total TL intensity (nC), and *Rb* is the reading of the background intensity (nC). The amount of radiation dose received by each radiation worker is calculated using equation (2).

$$D = Rn \times Fk \times Fke \qquad (2)$$

D is the received radiation dose (Gy), Fk is the calibration factor (mGy/NC), and Fke is the energy correction factor. The value of the radiation dose received by radiation workers is equipped with a standard deviation, which is calculated using equation (3).

$$SD = \sqrt{\frac{\sum(D - \overline{D})^2}{n - 1}} \qquad (3)$$

SD is the standard deviation, D is the radiation dose received by radiation workers (mSv), $\overline{D}$ is the average radiation dose received by each radiation worker, and n is the number of samples.

RESULTS AND DISCUSSION

Unand Hospital's radiotherapy facility comes from X-ray exposure by LINAC dual Energy (photon and electron), as shown in Figure 2a. In addition, the CT-Simulator, C-Arm and Brachytherapy radioactive compound Ir-192 (Figure 2b) were built to support the radiotherapy facility.

(a)   (b)
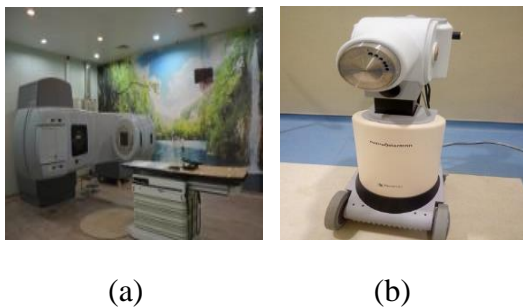
Figure 2. (a) LINAC Teletherapy Device and (b) mHDR Brachytherapy Device Located at Unand Hospital

One of the benefits that Unand Hospital has is in the area of radiotherapy, which opened in June 2018. Receiving radiation doses, especially for radiation workers, is a result of services provided by the radiotherapy installation that range from planning to therapy. Each step involves the use of ionizing radiation from a CT simulator, Linac, and brachytherapy. It is essential to track and assess how radiation workers are accepting doses.

The 235 TLD reads for 16 Occupational Exposures were achieved from 2018 to 2022. As shown in Table 1, the 16 occupational exposure consisted of 33.3 % (N = 5) Radiotherapists, 20 % (N = 3) radiation oncologists, 13.3 % (N = 2) medical physicists, 6.7 % (N = 1) for each electro medical and sculptor. In 2018, the number of employees was seven, then rose 50% each year after reaching 16 in 2019 and 2020.

Table 1. Number and Percentages of Workers Based on Occupation

Occupation	N	%
Radiation Oncologist	3	20
Medical Physicist	2	13.3
Radiotherapists	5	33.3
Sculptor	1	6.7
Nurse's	3	20
Electromedical	1	6.7
Total	15	100

The year after, one employee resigned, which led to the total number of employees becoming 15 in 2022 (Figure 3). The effective annual dose for occupant exposure based on the yearly workload for 900 patients is 0.684 (±0.454) mSv. The annual effective dose for all occupants during the observed period was between 0.164 mSv (year 2022) and 1.393 mSv (2018) (Figure 4). An annual effective dose (Equation 2) and deviation standard (Equation 3) were calculated for each occupancy exposure group.
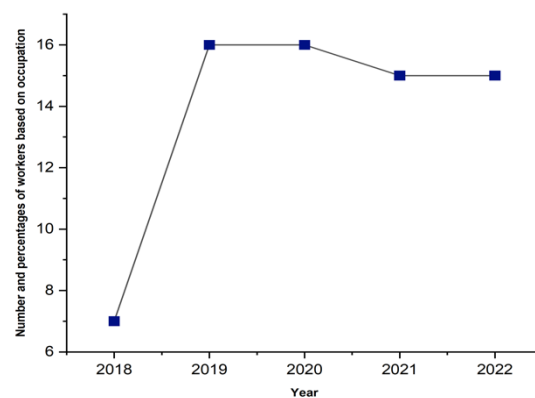
Figure 3 Total Number of Radiotherapy Workers (*x*) against Years of Observation (*y*)

The average radiation dose received by radiation workers was very high in 2018 when compared to other years. This can be caused by the number of radiation workers in 2018 being less compared to other years, resulting in increased contact with radiation. In addition, in 2018, this was the first time Unand Hospital ran the radiotherapy service, so it was still in the equipment testing stage.

Table 2 shows that among all employees during the research period, medical physicists accepted the most significant yearly effective dose. The medical physicist has the highest exposure, with an amount of 1.695 mSv, according to the yearly analysis. According to earlier research, medical physicist contamination is expected to increase over the next few years (Elshami et al., 2022; Miller, 2008; UNSCEAR, 2008). All forms of occupational exposure also yielded comparable outcomes. The annual dose of the worker decreases when the number of employees exposed to occupancy exposure increases, as shown in Figure 5.

Medical physicists at Unand Hospital work to provide services in two types of radiotherapy: Brachytherapy and Linac dual-energy (Photons and electrons). In addition, medical physicists are also seen in the planning process of radiotherapy using CT Simulator. Another task load of a medical physicist is to perform daily checks for radiotherapy equipment that will be used for therapy. This causes medical physicists to receive higher radiation doses than other workers. The subsequent effective dose recipients are radiotherapists, followed by radiotherapy specialists. The deviation for electromedicine and sculptor is zero due to the fact that there is only one person for this section, according to Table 1.

Table 2. Average, Max, Min and SD for Annual Effective Dose (HP 10) in mSv

Occupational	Average HP 10	Max	Min	SD
Radiation Oncologist	0.711	0.856	0.468	0.212
Medical Physicist	0.996	1.695	0.370	0.665
Radiotherapists	0.654	0.894	0.500	0.177

Occupational	Average HP 10	Max	Min	SD
Electromedical	0.342	0.342	0.342	0
Sculptor	0.746	0.746	0.746	0
Nurse's	0.536	0.700	0.425	0.145

Table 3 shows a comparison of work radiation doses in several countries. Unand Hospital's medical physicists' annual radiation dose is above Saudi Arabia's (0.50 mSv) as the lowest annual radiation dose rate. However, Unand Hospital Medical Physics' annual radiation dose rate is still below countries like Greece (3.63 mSv), Kuwait (1.35 mSv), and Chile (2.40 mSv), which proved still allowed cause below dose limitation. Furthermore, a protection improvement protocol is necessary for all occupancies exposed to wear personal dosimeters while on duty for further evaluation and to prevent deterministic effects of radiation.
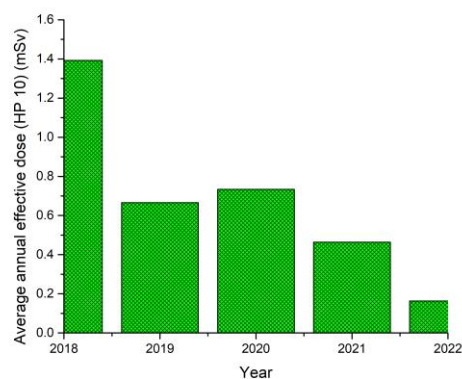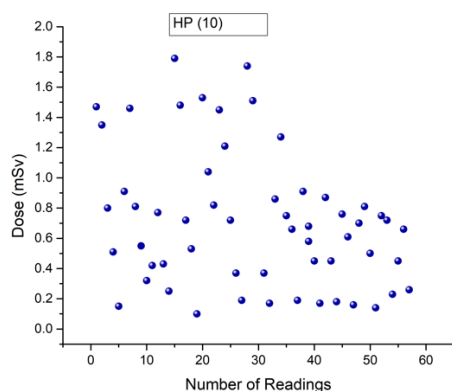

Figure 4. Average Annual Effective Dose (HP 10) in mSv for Medical Workers Per Year

COVID-19 entered Indonesia at the end of 2019, more precisely in December, but was detected at the beginning of the year around March 2020. At this time, all services in the medical field changed drastically, including services at the Radiotherapy Installation of Unand Hospital. Restrictions on the number of radiotherapy patients reached 30 per cent, so the use of radiotherapy equipment at Unand Hospital also decreased. This decrease in equipment use did not affect the value of radiation doses received in 2020, as shown in Figure 4, where the average amount of

radiation dose received by workers ranks second.

Table 3. Comparative Analysis of Effective Doses in Radiotherapy for Different Countries (Weizhang, et al., 2005; Nassef, et al., 2017; Alashban, 2022)

Data Range	Country	Radiotherapy (mSv)
2000-2022	Canada	0.76
2000-2022	Chile	2.40
1992-1994	Kuwait	1.35
1996-2000	China	0.90
1997-1998	Greece	3.63
2007-2011	Pakistan	0.88
2018-2019	Saudi Arabia	0.50
2018-2022	Current study	0.66

Figure 5. Distribution of Average Annual Effective (HP 10) in mSv for All Workers (2018-2022).

Nassef, et al (2017) reported the results of their research on radiation doses received by radiation workers in one of Saudi Arabia's teaching hospitals. The results obtained by Nassef, et al (2017) showed that the annual average effective dose for diagnostic radiology, nuclear medicine, and radiotherapy workers was found to be 0.66 mSv (diagnostic), 1.56 mSv (nuclear medicine), and 0.28 (radiotherapy) mSv respectively with the number of workers observed 100 people. In Table 3, it can be seen that the radiation dose received by radiation workers in the radiotherapist of Unand Hospital is 0.66 mSv, which is 0.38 mSv higher than the research conducted by Nassef, et al (2017). Nevertheless, the results of the measured annual dose are far

below the internationally recommended dose limit of 20 mSv (ICRP, 2007).

Figure 5 displays the distribution of effective doses received by radiation workers from the TLD readings of all radiation workers. TLD readings were taken every three months (December-February, March-May, June-August, and September-November), but Figure 4 depicts the average dose each year for all radiation workers. This analysis is conducted annually in accordance with the annual dose value limits issued by the national and international radiation regulatory agencies to a maximum of 20 mSv (Wrixon, 2008). The highest radiation dose distribution was on the TLD used by medical physicists at 1,790 mSv in 2018, and the lowest was 0,160 mSv by radiotherapists. All dose distributions from the TLD readings of radiation workers at Unand Hospital did not exceed the dose limit values by international organizations. However, it is essential to know that even the smallest dose of radiation received by workers can have a negative impact on radiation workers (classified as a stochastic effect that does not recognize the threshold dose) (Guo et al., 2021).

Whenever performing radiation-related work, it is essential to always wear a personal radiation monitoring device. With proper radiation dose monitoring, precautions and safety measures can be taken to protect workers in Radiotherapy and ensure effective treatment for patients without endangering medical staff. Through radiation dose monitoring, workers exposed to high or excessive doses can be immediately identified and receive appropriate medical treatment. This can help avoid severe long-term health impacts of unintended radiation exposure in radiation workers.

CONCLUSION

The radiation dose received by Radiotherapy Installation personnel has been analyzed. The annual effective dose exposure to radiation is still safe under

national or international regulations. However, the process of improving radiation monitoring is vital to limit radiation interaction, especially for medical physicists, who are the most vulnerable to radiation exposure. This study still has shortcomings, especially since the number of radiation workers examined is still relatively small.

Future research will focus on the compliance of health workers in the radiation work environment with the use of individual radiation dosimeters. It is hoped that in the future, every radiation worker, especially in radiotherapy installations, will implement radiation protection properly. In addition, the use of individual dosimeters in every patient handling activity in the radiation environment needs to be an essential concern.

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AUTHOR CONTRIBUTIONS

RF: Research Concept and Design, Collection and/or Assembly of Data, Data Analysis and Interpretation, Writing The Article, and Final Approval of The Article; DM and AM: Critical Revision of The Article; LAR: Collection and/or Assembly of Data; MA: Data Analysis and Interpretation; and FD: Collection and/or Assembly of Data, and Critical Revision of The Article.

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